Measuring the Impact of Universal Health Care on Longevity Risk

(A case for Rwanda)

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Project contains no material previously published or written by another person except where due reference is made in the Research Project itself.

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ABSTRACT

Longevity remains to be a complex risk that is ever evolving and requires great understanding. Improved healthcare through the roll out of Universal Health Care is also seen to enhance this risk through improved mortality rates. This leaves individuals, governments and benefit providers at risk because they can not appropriately make financial plans leading to major losses or inadequate funds and reserves. This study expounds on longevity risk and its impact on the interested parties.

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List of Abbreviations

The following are the abbreviations and their respective definitions as used in this study:

UHC - Universal health coverage

WHO - World Health Organisation

CBHI - Community Based Health Insurance

Chapter 1: Introduction

1.1 Background information

1.1.1 Definition and brief elaboration of key concepts

According to the World Health Organization, Universal Health Coverage (UHC) means that "All people and communities can use the promotive, preventive, curative, rehabilitative and palliative health services they need, of sufficient quality to be effective, while also ensuring that the use of these services does not expose the user to financial hardship" (WHO, 2020).

Over the past several years, we have observed an increase in life expectancy globally and Rwanda is no exception. Life expectancy is the average period that an individual may be expected to live. In 2019, the life expectancy at birth was 68.75 years compared to 52.33 years in 2004 when UHC was first rolled out (World Population Prospects [WPP], 2019). This may be partly attributed to improved healthcare and better living standards. Increased life expectancy is a positive result but in turn, it enhances longevity risk to a great extent. However, other factors affect life expectancies such as lifestyle choices, genetics, nutrition, income, geographical location, diseases, terminal illnesses, and pandemics such as the one currently being experienced, COVID-19 and in turn, higher mortality directly reduces the life expectancy.

Longevity risk may be defined as the risk that the actual survival rates and life expectancy exceeds the expected rates or any assumptions made earlier, resulting in greater cash flow needs. Longevity risk is not diversifiable so it might strain the resources available to individuals, pension schemes, life insurers and governments because they cannot adequately plan their future financial liabilities due to the uncertainties involved. Increased life expectancy requires that governments, life insurers and defined benefits schemes keep paying out benefits for longer periods and individuals may outlive their income or savings.

1.1.2 Identification of main developments in the study area and any gaps

Achieving Universal Health Care is a global concern as stated by the World Health Organisation (WHO) which is also in line with the Sustainable Development Goals rolled out in 2015. So, all WHO member states, Rwanda included, committed to achieving UHC by 2030.

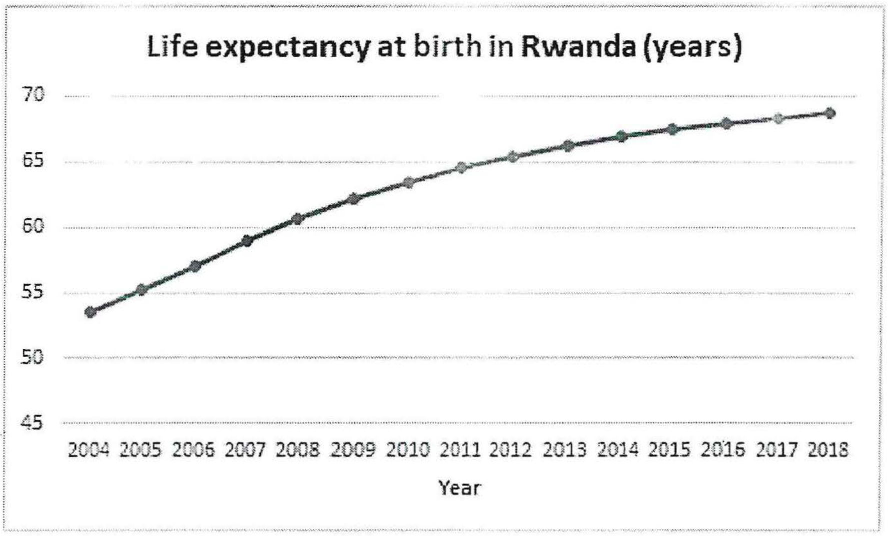
Rwanda rolled out a community-based health insurance scheme that enables them to subsidize costs for their citizens. Over 90% of the citizens are part of this scheme. There has been a lot of sensitisation to the citizens on disease prevention as well as a good breakdown of health care services to the grass-root level. These steps have improved UHC in Rwanda and it is deemed to be doing well as a developing country.

However, slightly more than half of the world's population still does not have access to basic healthcare (McNeill & Jacobs, 2019). The major challenge in making Universal Health Care a reality is lack of adequate funding. This exposes the citizens to some financial risk and hence we are not certain whether this program will be sustainable in the long term. This sector also lacks proper key progress indicators locally and internationally.

1.1.3 Brief conceptualization of the study (context, trends)

Life expectancy in Rwanda is seen to be on the rise every other year, after the brutal genocide in 1994, which exposes them to increased longevity risks. This risk is driven by various factors that should be well understood for proper risk mitigation. Health interventions and social development are among the major factors affecting life expectancy (Chan & Kamala, 2015). However, there is a lot of uncertainty surrounding mortality projections (Brouhns, Denuit & Vermunt, 2002) as well as measures of progress in terms of UHC.

Figure 1: Life expectancy at birth in Rwanda



Source: The World Bank

1.2 Problem Statement

There has been an increased emphasis on healthcare that has led to the roll-out of UHC guidelines that assures all people of access to good quality, basic health care services without causing financial strain. UHC has therefore been embraced by all WHO member states which include developing countries such as Rwanda. Rwanda seeks to target the poorest members of the community by improving the quality and accessibility to healthcare services

As we all know, with every action there is an implication and it has been a positive one in this case. The population is seen to be experiencing an overall increase in life expectancy due to an increase in the Healthy Life Expectancy as well as the Life Expectancy at Birth (Ranabhat, Atkinson, Park, Kim, & Jakovljevic, 2018).

Increased life expectancy comes at a cost that is the increase in longevity risks. This affects individuals, the government, life insurers and defined benefits pensions as they might have to pay out benefits for longer periods. The financial strain of healthcare might have been taken away from the citizens however, this leaves the benefit-providers more exposed to financial risk.

1.3 Research Objectives

This paper seeks to determine the impact of Universal Health Care on longevity risks by forecasting the Universal health care index assuming the current trends will continue. Thereafter, we will be able to see the financial impact on individuals, the government, life insurers and the defined benefit pension schemes.

This study seeks to answer these questions:

- What is the current trend in life expectancy?
- What will the life expectancy trend be like as the universal health care changes?
- What is the financial impact of the changes in UHC?

1.4 Significance of the research

1.4.1 Identification of beneficiaries

Failure to acknowledge the impact of longevity risks could expose benefit providers to financial risks due to benefits being paid out for longer periods than had been projected. This study highlights the impact of UHC on life expectancy, which seeks to benefit individuals, the government, life insurers and defined benefits pensions.

1.4.2 How will they benefit?

This study will enable the benefit-providers to see the financial implications brought about by longevity risks. Based on the highlighted issues, this will allow for better planning and allocation of financial resources while ensuring solvency and liquidity throughout while still having some emergency cash at hand. The benefit providers should always be on the lookout for major factors affecting longevity risks such as UHC and therefore adequately plan for them.

Chapter 2: Literature Review

This chapter reviews relevant literature and theories available on mortality risks, longevity risks and Universal Health Care.

2.1 Theoretical and Empirical Framework

2.1.1 Measuring Universal Health Care

Achieving Universal Health Care was adopted as one of the Sustainable Development Goals however, we cannot measure its long term effect adequately (Carrin, James & Evans, 2005).

Based on the WHO fact sheet on UHC, it is appropriate for the UHC index to be based on the degree of coverage. This is in terms of the financial protection being provided by this scheme, the proportion of the population that has been covered and the services being offered. However, most measures of UHC focus on the costs paid out of pocket as a measure of coverage which has its shortcomings (Adam, Daniel, Patrick & Leander, SPRING 2016).

Based on the simple model proposed by Adam et al., 2016, we might measure UHC using an index that is the geometric mean of the two:

$$\text{UHC} = SC^{0.5} * FP^{0.5}$$

if we weigh service coverage and financial protection equally.

where SC is a service coverage index and

FP is a financial protection index.

Service Coverage is based on treatment and prevention. However, this is based on the need covered by the services, which is quite subjective considering the needs vary from one person to another. This makes this measure complex. WHO uses four categories to measure coverage in various countries:

- Reproductive, maternal, newborn and child health

- Infectious diseases
- Non-communicable diseases
- Service capacity and access.

Financial Protection considers whether the healthcare payments made may exceed the family's budget and whether the payments may push the family into financial distress (Wagstaff & van Doorslaer, 2003).

Healthcare reforms aim to promote preventive healthcare and provide more primary healthcare services with the goal to improve the healthcare of the population (Jakovljevic, Arsenijevic, Pavlova, Verhaeghe, Laaser & Groot, 2017). Based on this progress we require appropriate demographic indicators, mortality indicators and health-capacity indicators. Some of the indicators of an effective health system include antenatal care coverage, percentage of births attended by skilled birth attendants, child immunization rates, the proportion of children brought to a health-care facility for specific treatments, and the rate at which family planning needs are being met (WHO, 2014).

2.1.2 Modelling Mortality and Life Expectancy

There is a lot of uncertainty surrounding mortality projections (Brouhns, Denuit & Vermunt, 2002) as well as measures of progress in terms of UHC. However, we require appropriate projections of mortality for the proper estimation of future costs (Brouhns et al., 2002).

Mortality rates are not only a function of age. Other factors need to be considered and they are included as parameters when modelling mortality rates (Booth & Tickle, 1970). Due to this, the one-factor models may not be appropriate for this study.

There are various models to project mortality such as Lee - Carter and the Poisson log-bilinear regression model, which is an enhancement of the Lee-Carter model. Proper mortality projections reduce the longevity risks that arise.

2.1.2.1 Lee Carter Model

This is a simple model that projects mortality as a function of a single time index using least squares. It is also a better alternative to direct time-series forecasts as it is seen to have narrower confidence intervals (Lee & Carter, 1992). The model uses a few parameters compared to the other models therefore, it is easier to use. Lee Carter is currently the most popular method of mortality forecasting.

Lee & Carter (1992) proposed:

$$\ln m_{x;t} = a_x + b_x k_t + \varepsilon_{x,t}$$

where $m_{x;t}$ is the central mortality rate at age x in year t;

a_x is average (over time) log-mortality at age x. So, exp a_x represents the general shape of the age-specific mortality profile;

b_x measures the response at age x to change in the overall level of mortality over time;

k_t represents the underlying time trend in year t;

$\varepsilon_{x,t}$ is the residual i.e. factors not captured by the model. They are IID with a normal distribution.

This model, however, assumes that the errors are homoscedastic which may not be accurate due to the great variance in mortality at older ages. Also having b_x as a constant is quite debatable because the sensitivity is expected to change over time but despite the limitations, Tuljapuktar & Boe (1998), recommended using the Lee-Carter model to model mortality rates.

2.1.2.2 Poisson Log-Bilinear Regression Model

This model is based on the number of deaths and the force of mortality. The number of deaths takes up a Poisson distribution because it is a counting random variable while the force of mortality takes up the log-bilinear form.

$D_{x;t} \sim \text{Poisson}\,(E_{x;t}\mu_{x;t})$

where $D_{x;t}$ is the number of deaths in year t of lives aged x

$E_{x;t}$ represents the exposure to the risk of death

This tackles the problem of homoscedasticity in the Lee-Carter model. The assumption of homoscedastic errors is quite unrealistic. Instead, we make use of confidence intervals which helps take into account the various sources of variability (Brouhns et al., 2002).

2.2 Research Gap

Life expectancy is a reflection of the mortality rates and the healthcare system of a particular region (Jakovljevic et al, 2017). These models used to project future mortality rates fail to account for unexpected shocks and developments such as Universal Health Care that may impact mortality rates. This exposes individuals and benefit providers to greater risks which may not be adequately covered by the income, savings or reserves. This study aims to incorporate such developments for better mortality projections in order to protect individuals and benefit providers.

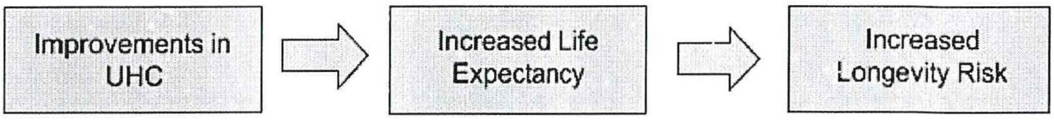
The impact of UHC on mortality rates has not been tackled explicitly and we cannot precisely evaluate the relationship between these two factors (Ranabhat et al., 2018). This study aims to seek an appropriate relationship between these two factors.

Chapter 3: Research Methodology

This chapter explains the various stages followed in the completion of the study. This is in terms of the collection, measurement and analysis of data. We can identify the various techniques used in the collection, processing and analysis of data in order to assess the impact of Universal Healthcare and medical improvements on life expectancy as well as the financial implications on the benefit-providers.

3.1 Description of Variables

This study claims that improvement in UHC leads to an increase in life expectancy at birth. In turn, this exposes the benefit-providers to increase longevity risks. This affects their finances as they may end up paying out benefits for longer periods than expected.



The independent variable is the improvement in mortality and longevity in relation to life expectancy.

The dependent variable is the life expectancy of the general population.

The intervening variable is the universal healthcare trends and its impact on life expectancy.

3.2 Research Design

This research uses a quantitative approach to measure the progress in UHC as well as project the expected life expectancy. However, a qualitative approach will be used to show the impact of the development in UHC.

Assumptions

The data used is correct and bias free.

The changes in mortality follow a constant pattern.

Limitations

The predicted future trends may be different from the actual future trends. Certain factors may change and there may be unexpected events in future.

3.3 Population & Sampling

The population under consideration is the Rwandan population. There is information readily available in the world bank database and the UNICEF global database.

The sample size is also based on the available adult mortality data. This would be appropriate due to the law of large numbers so it would reduce any major deviations.

3.4 Data Collection

The study uses secondary data on adult mortality in Rwanda and data available in similar studies.

Measures of the UHC index are based on the information provided by the World Health Organisation.

We aim to use time series analysis to study the trends in life expectancy since the health reforms started in Rwanda. Also in order to quantify the impact of Universal Health Care, we need to keenly study the reforms that have taken place in the health sector. We shall consider the features of the UHC index. The methodological approach that will be used to project mortality is the Lee-Carter model.

Life Expectancy at Birth

This is a measure of the average number of years one is expected to live from birth considering the current conditions remain (Zhao, Liang, Wenke Zhao & Hou, 2013)

The formula is: $\frac{T_x}{l_x}$

where T_x is the total person-years lived the lives being considered

l_x is the number of lives aged x being considered

Lee-Carter Model (Lee & Carter, 1992)

$$\ln m_{x;t} = a_x + b_x k_t + \varepsilon_{x,t}$$

where: $m_{x;t}$ is the central mortality rate at age x in year t;

a_x is average (over time) log-mortality at age x;

b_x measures the response at age x to change in the overall level of mortality over time;

k_t represents the changes in mortality in year t;

$\varepsilon_{x,t}$ is the residual. These are variations that are not captured by the model

The central rate of mortality of age x in year t is defined as;

$$m_{x;t} = D_{x;t} E_{x;t}$$

where $D_{x;t}$ is the number of deaths in year t of lives aged x

$E_{x;t}$ represents the exposure to the risk of death

Vector a is the average of log rates of mortality over time.

Vector b and k are based on the SVD of the residuals. These vectors will be able to reflect the changes that have arisen as a result of UHC.

Chapter 4: Analysis, Results and Discussions

4.1 Sources of Data

My analysis is based on Rwanda's mortality data available from the World Bank Database and child mortality data available on the UNICEF database. The database provides information on several countries for different time periods in terms of infant mortality, adult mortality, mortality for every sex, crude death rates as well as other economic indicators.

I chose Rwanda as opposed to Kenya because it is a third world country in Africa however, they rolled out UHC earlier on compared to Kenya therefore, more data is available for the study.

4.2 Description of software used

Accurate mortality projections are required to make appropriate financial decisions. For data analysis, I made use of the RStudio software and Microsoft Excel.

4.3 Assumptions

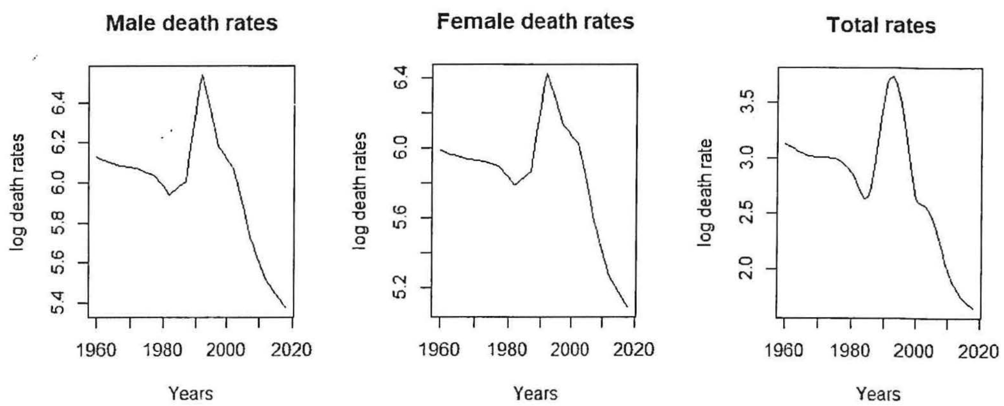
The following assumptions were made:

- Life expectancy was used to measure health because it is inversely correlated with overall death (Wen, Tsai & Chung, 2008)
- The age structure of the population is based on the percentages of the 2014 national census.
- Crude death rates represent $m_{x;t}$
- The change in mortality patterns is constant

4.4 Data Analysis

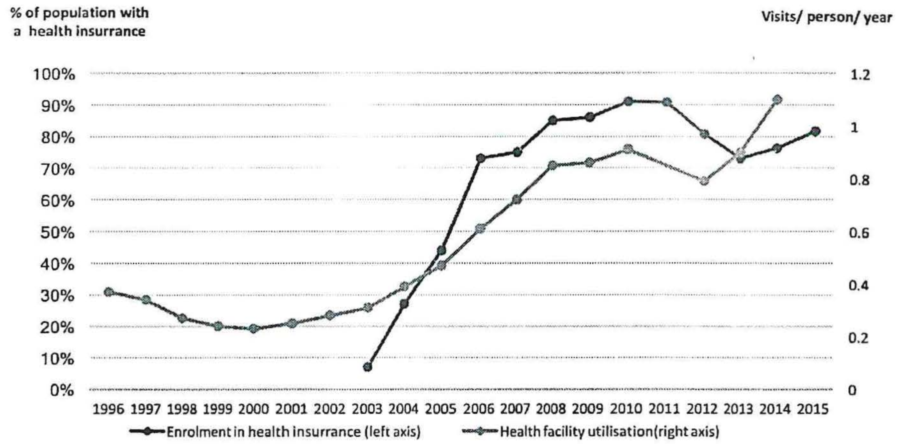
The data available from the World Bank was imported through the Import Dataset code. The adult crude death rates (for every 1000 people) between 1960 and 2018 were then plotted and the results are as follows:

Figure 2: Log death rates in Rwanda from 1960 to 2018



The results confirm a decline in death rates over the years. This is also seen after UHC was introduced in Rwanda in 2004. UHC in Rwanda is measured based on the uptake of CBHI and the financial protection offered by the insurance. The table below shows the percentage uptake of CBHI.

Figure 3: Percentage uptake of CBHI in Rwanda



Source: Science Direct

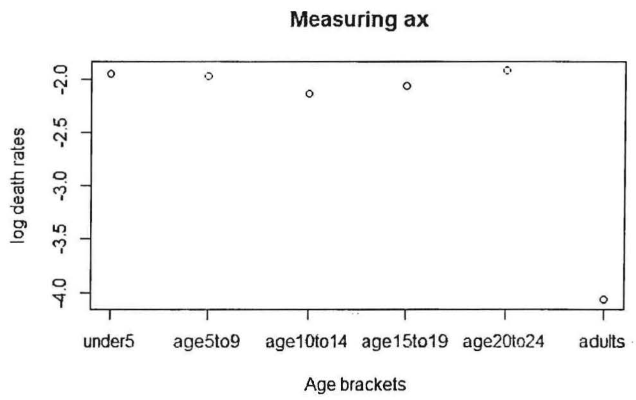
4.5 Fitting the model

The model used is the Lee-Carter model:

$$\ln m_{x;t} = a_x + b_x k_t + \varepsilon_{x,t}$$

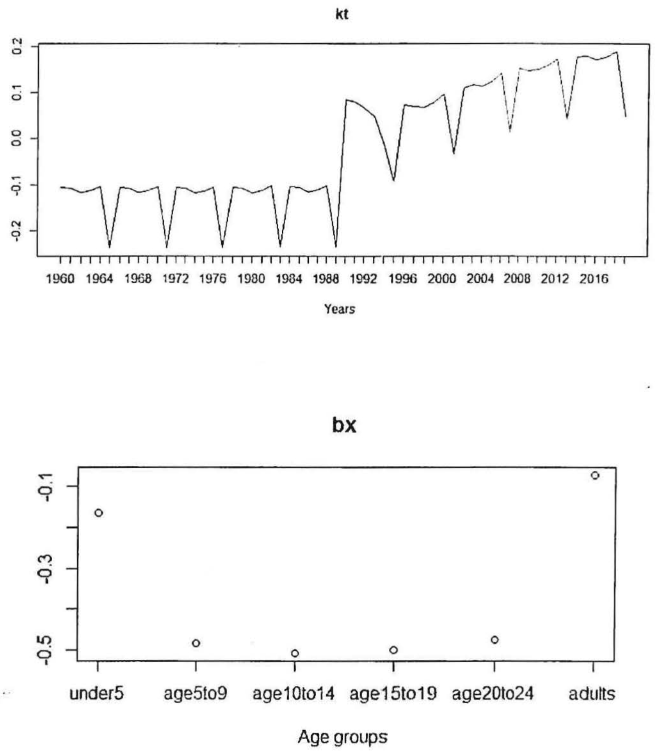
a_x represents the general mortality for each age x. It is calculated as the average of the logarithm of the death rates over several years. The various values for different age groups are shown in the graph below.

Figure 4: Lee-Carter estimation of parameter a_x



$b_x k_t$ is estimated using the singular value decomposition. We make use of the first right and the first left singular vectors of the matrix $(ln\, m_{x;t} - a_x)$(Haberman & Renshaw, 2008). k_t reflects the effect of the calendar year while b_x reflects the impact as of a specific age group.

Figure 5: SVD estimation of b_x and k_t



The results reflect that those under 5 years of age and adults on average experience greater mortality rates. This may be attributed to their exposure to many health conditions and various diseases as they are more vulnerable. Also, the sudden hump in the 1990s may be attributed to the 1994 genocide which lead to increased death rates.

4.6 Actuarial projections

a_x and b_x are assumed to be constant so, the forecast is based on projecting k_t. The changes in k_t also reflect the expected improvements in UHC. The projections of k_t make use of the random walk with drift model.

$$k_t = k_{t-1} + \theta + \varepsilon_t$$

where $\theta = \frac{k_T - k_1}{T-1}$

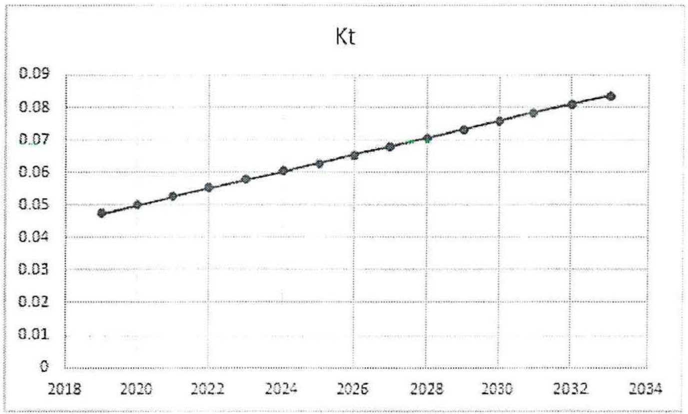
k_T is the last calculated k_t

k_1 is the first calculated k_t

$T - 1$ is the time difference

θ is a positive value, 0.0026, so k_t is reflecting an improvement in mortality just as the levels of UHC coverage are expected to be increasing with time.

Figure 6: k_t projections



The longevity risk facing the country is clearly highlighted and the life offices and the government should accurately account for this when making financial plans. Otherwise, this could lead to greater benefit payments. The reserves and premiums collected may not be adequate to cover and major losses may result as well. Longevity risk is seen to be developing slowly and it takes time before it can be realised.

Chapter 5: Conclusions & Recommendations

5.1 Conclusion

This research study focused on Rwanda which is a developing country that had rolled out UHC in the early 2000s so it was a good representation of other third world countries embracing UHC. The study sought to determine the existence of longevity risk and the Lee-Carter model was used to project the mortality parameters. The results reflect a decrease in mortality and an increase in the UHC coverage as the years go by. So it is possible that the citizens may live for longer periods than expected. Failure to consider the longevity risks may lead to major losses due to inadequate premiums and reserves.

5.2 Limitations

However, there are several limitations such as:

- Mortality data is not readily available for all age groups so the study made use of the available grouped data.
- The mortality experience is assumed to be constant because the Lee-Carter model makes use of constant parameters and this may not be realistic.

5.3 Recommendations

Longevity risk has been proven to exist so risk mitigation processes should be put in place to counter its effects. Longevity risk is also accompanied by other risks such as interest rate risk, inflation risk, credit risk etc. Therefore, this makes longevity risk very complex. Therefore, parties involved should also be informed on the risk assessment, measurement and mitigation techniques.

Derivatives may be used by benefit providers to shield their funds from this risk. Insurance is also another viable option so the benefits provider passes on the risk to the insurer.

It is essential that the mortality tables are updated following these developments so as to prevent under the provision for future benefits.

List of References

Adam Wagstaff, Daniel Cotlear, Patrick Hoang-Vu Eozenou, Leander R. Buisman (SPRING 2016). Measuring progress towards universal health coverage: with an application to 24 developing countries, *Oxford Review of Economic Policy*, Volume 32, Issue 1

Booth, H., & Tickle, L. (1970). Mortality Modelling and Forecasting: a Review of Methods.

Bojuan B. Zhao, Xiangliang Liang, Wenke Zhao, Delong Hou. (2013) Modelling of group-specific mortality in China using a modified Lee-Carter model. Scandinavian Actuarial Journal 2013:5, pages 383-402.

Brouhns, N., Denuit, M., & Vermunt, J. K. (2002). Measuring the longevity risk in mortality projections. Bulletin of the Swiss Association of Actuaries (2)

Carrin, G., James, C., and Evans, D. (2005). Achieving universal health coverage: developing the health financing system. Geneva: World Health Organization

Chan, M. F., and Kamala Devi, M. (2015). Factors affecting life expectancy: evidence from 1980-2009 data in Singapore, Malaysia, and Thailand. Asia Pacific J. Public Health 27, 136–146.

Haberman, S., & Renshaw, A. (2008). New developments of the Lee-Carter model for mortality dynamics.

Jakovljevic, M. M., Arsenijevic, J., Pavlova, M., Verhaeghe, N., Laaser, U., & Groot, W. (2017). Within the triangle of healthcare legacies: comparing the performance of South-Eastern European health systems. Journal of medical economics, 20(5), 483–492. https://doi.org/10.1080/13696998.2016.1277228

Lee, R.D., & Carter, L. (1992). Modelling and forecasting the time series of US mortality. Journal of the American Statistical Association

McNeill, K., & Jacobs, C. (2019). Half of the world's population lack access to essential health services – are we doing enough? https://www.weforum.org/agenda/2019/09/half-of-the-world-s-population-lack-access-to-essential-health-services-are-we-doing-enough/

Ranabhat, C. L., Atkinson, J., Park, M. B., Kim, C. B., & Jakovljevic, M. (2018). The Influence of Universal Health Coverage on Life Expectancy at Birth (LEAB) and Healthy Life Expectancy (HALE): A Multi-Country Cross-Sectional Study. Frontiers in pharmacology, 9, 960.

WHO. (2014). The health of the people: what works: the African regional health report 2014.

Rwanda Ministry of Finance and Economic Planning (Revised 2012). Vision 2020.

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, Volume II: Demographic Profiles

Wagstaff A. & van Doorslaer E. (2003). Catastrophe and Impoverishment in Paying for Health Care: With Applications to Vietnam 1993–1998. Health Economics.

Wen, C. P., Tsai, S. P., & Chung, W. S. (2008). A 10-year experience with universal health insurance in Taiwan: measuring changes in health and health disparity. Annals of internal medicine.

WHO (2020). What is UHC? http://www.who.int/features/qa/universal_health_coverage/en/

World Health Organisation. Universal Health Coverage factsheet (2019). https://www.who.int/news-room/fact-sheets/detail/universal-health-coverage-(uhc)